APPLICATION OF A RUBY LASER TO HIGH-SPEED PHOTOGRAPHY

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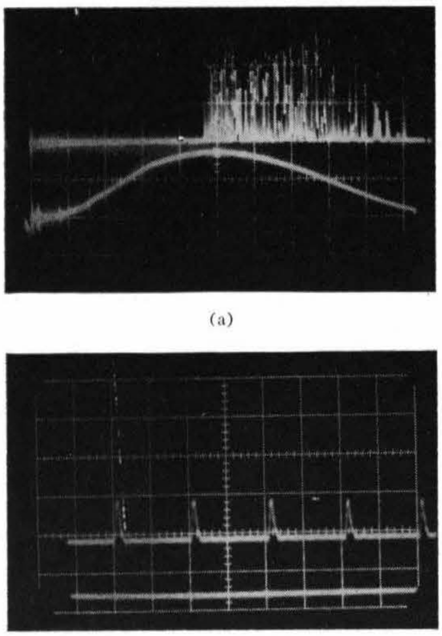
Multiple pulsing of a ruby laser has been achieved and incorporated into a high-speed camera. The pulsing is accomplished by means of cavity Q spoiling techniques utilizing a Kerr cell. A rotating mirror camera is used with the laser acting as a stroboscopic light source to record the events. Framing rates of over a million frames per second with exposure times of less than 30 nsec are easily obtainable. This in conjunction with the highly intense, monochromatic, coherent and collimated nature of the laser light makes the high-speed laser camera desirable in many areas of research.

The Q spoiling technique of obtaining very short duration pulses has been reported by McClung and Hellwarth.[1] In their work a single "giant pulse" was obtained and studied in detail as a means of achieving a better understanding of the phenomena involved. In this letter the major item to be reported is that of achieving multiple pulses and their utilization in high-speed photography. As a consequence several interesting aspects have occurred, such as a region of repetition rates in which a stability of the amplitude of the pulses occurs. The location of this region is a function of the laser cavity length.



(a)

(b)

Fig. 1—Oscilloscope record of laser output: (a) Operating in normal mode; upper trace is laser output and lower is pumping light. Time scale is 100 μsec per division. (b) Multiple laser pulses with Kerr cell operating at 500 kc per second.

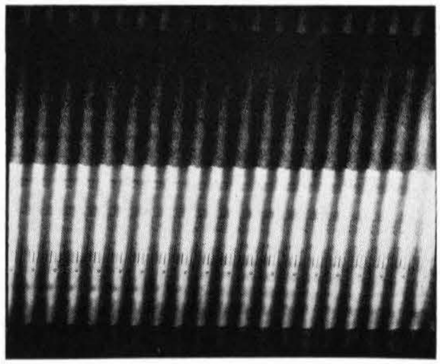


Fig. 2—Resolution test photograph of microscope scale. Small divisions are 100 microns apart.

The laser used in these experiments was a 3-inch long $\frac{1}{4}$-inch diameter ruby rod enclosed in a cylindrical cavity of elliptical cross section. The ruby rod was located at one focus of the ellipse and the pumping light (an EGG FX-42) at the other. The walls of the cavity were highly polished, thereby furnishing a very efficient means of pumping energy input. A TIR 90°-oriented ruby rod with 0.04 per cent chromium ions was used. The Fabry-Perot interferometric cavity was formed between the wedge end of the ruby and an external dielectric mirror which was located 13 inches away for the figures shown here. The reflectivity of this mirror was 90 per cent at 6943 Å. The Kerr cell used as a Q spoiler was filled with nitrobenzene and was operated in the on-off-on mode with a duration of 0.2 μsec for the off position.

Fig. 1 shows the results of this method of Q spoiling with Fig. 1(a) showing the laser operating in the normal mode with the Kerr cell inoperative. In Fig. 1(b) the laser output is seen for the Kerr cell operating at 500 kc per second. Due to poor frequency response of the photodiode used it is impossible to compare the amplitudes of these pulses with those of the laser operating in the normal mode. For the same reason the duration of these pulses is known to be shorter than that indicated in Fig. 1(b) (approximately 50 nsec). By changing the cavity length repetition rates of over 1 Mc have been achieved.

Fig. 2 illustrates the resolution possible. It shows several frames taken at a rate of 200,000 frames per second of a microscope scale on which the smallest division is 100 microns. The image speed over the film plane was approximately 100,000 inches per second. Fig. 3 shows a bubble being generated in water by means of an electrical discharge. These three frames were taken at a demagnification of 2 and at a rate of 200,000 frames per second. It is of particular interest to note the shock wave in the early frames; at a later time reflected shocks were also observed. (Note: a portion of each frame was lost due to the use of a wedge-shaped rotating mirror.) It is also of interest to note that in order to achieve the proper exposure in these pictures a reduction of intensity by a factor of 800 was necessary.

Fig. 3—Generation of a bubble in water by an electrical discharge (taken at 200,000 frames per second).

Thus far the laser camera has yielded excellent results in flow visualization both by direct observation and by means of scattered light from flow tracers, in dynamic photoelasticity and in high-speed Schlieren observations. In particular, flow visualization by means of forward scattered light from spheres 0.285 micron in diameter have been obtained. Several other areas of application are being investigated for future work. For example, the high intensity, rapid rise time and accuracy of frequency control for a series of pulses immediately suggest that such a device could be utilized in radar.

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[1] F. J. McClung and R. W. Hellwarth, "Giant optical pulsation from ruby," *J. Appl. Phys.*, vol. 33, pp. 828–829; March, 1962.

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